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Micro-watershed level population based fuelwood consumption dynamics: Implications of seasonal vs. annual models for sustainable energy resource planning

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ABSTRACT

Most developing countries such as India use biomass as a primary source of energy especially in domestic sectors in the rural area. The increasing population exerts more pressure on the biomass resource thereby initiating energy crisis in the region. The issue of shortage of fuelwood in the remote mountain regions is increasing since the alternative energy resources have limitations either due to poor economic condition of the people, complex technology involved or being inaccessible due to remoteness. It is also seen that the use of traditional biomass as a source of energy will improve the livelihood conditions of the people and it will give ecological benefits to the region if other associated factors like health, gender etc. are taken care of and thus the planners aim to focus on sustaining the natural fuelwood resources. The present paper attempts to predict the future fuelwood demand based on the present consumption pattern in the upland villages of Indian Himalaya. Major consumption characteristics such as fuelwood consumption at different altitude and per capita fuelwood consumption (PCFC) are studied. Population dynamics model is postulated in order to assess future population vs. fuelwood consumption scenario, thereby projecting the future population and the future fuelwood demand in the region.

It is observed that variations in fuelwood consumption exist at different altitudes in the hilly region. Mathematical modelling and time-series simulation model was proposed and validated model to predict the future expected demand of fuelwood resources in Phakot watershed. Based on the projected population and season based fuelwood requirements, the watershed will have a total fuelwood demand of 19,327 t in 2011 which is expected to reach 36,462 t in 2021. Such studies on the future resource demand trends will help in finding suitable region-specific and need-based alternative strategies for achieving sustainable fuelwood management at the micro-level.

Contents

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1. Introduction

The term biomass encompasses all energy forms derived from organic fuels of biological origins. It comprises all purposely grown energy crops, multipurpose plantations and byproducts (residues/wastes) which could be utilised in the form of fuel wood, charcoal and animal dung. These latter forms have dominated the world energy scene since the beginning of civilisation [1,2] and continues to do so. A large part of the rural population in developing countries like India meet more than one third of their total energy demand, principally in the domestic sector [3–10]. The latest projection by International Energy Agency [11] opines that, in the year 2030, 2.8 billion people will still rely on traditional biomass use for cooking.

On the other hand without access to modern energy resources, communities are dependent on traditional biomass such as fuelwood, charcoal and animal waste for cooking and heating [12]. Bioenergy is therefore nested at the intersection of three of the world's great challenges – energy security, climate change, and poverty reduction – and has received an enormous amount of attention in the past few years [13]. The scenario calls for proper biomass planning, especially in the Himalaya, as almost 90% energy demand is met with biomass resources [14].

Bioenergy can bring about other environmental benefits including the recovery of degraded land, reduction of soil erosion and protection of watersheds [15,16] and traditional biomass use is and will remain extremely important for global energy management and in particular for the poorest people [17]. Amongst developing countries such as India, bio-energy is a source of fuel for people surviving at the subsistence level but there is an acute shortage of this biomass fuel due to combined effects of diminishing supplies and growing demand in India [18]. Continued growth of population without enhanced productivity, along with a lack of ecological conservation, may jeopardize the self sufficiency of the village ecosystem and as such careful planning and management of the ecosystem is necessary if standard of living is to be improved [18]. Thus, the need arises to project future fuelwood requirements.

Availability of fodder, fuel and litter is important for the survival of the rural settlements since almost ninety percent of energy demand is met from the biomass in the Himalayan region [14]. The forest thinning, in government controlled forest and community forests, is largely the result of increased demand for fuel wood, fodder and manure for subsistence [19,20]. Therefore, forest resource-based economic development opportunities for local people [21] with a biomass plan that integrate resource conservation [14] will mitigate biomass stress in the region. The fuelwood consumption pattern in the Himalayan region was studied by different authors on migratory villages in Uttarkashi district [22], along altitudinal gradients in Garhwal Himalaya [23], for different tribal communities in Northeast India [24], Pindar basin [25], Himachal Pradesh [26,27], and Tehri district in Uttaranchal [28]. Awasthi et al. [22] observed a Spatio-temporal variation in resource extraction among the migratory villages of Uttarkashi. Administrative boundary level date based studies indicate that the firewood consumption is influenced by the climate and altitude of the place. On the other hand, the state level data are aggregated and hence unfit for use in developing specific policies for the sustainable use of forest resources [27]. Rural energy planning is a subject of village development and should focus on study of the village [29]. Consequently, the present study was conducted at micro-watershed level with reference to household energy consumption.

The variations in biomass consumption pattern at micro level are studied in this paper. Population changes over the decades are used to simulate fuel consumption patterns by using the fuelwood consumption (FC) models proposed in this paper. Hence, the present paper attempts to predict the watershed level fuelwood dynamics with respect to the population in order to have sustainable fuelwood management.

The annual values are arrived at by averaging over the recorded within-the-year observations but the quantity fuelwood consumption is found to be season dependent specially in the mountainous areas where distinct climate patterns are clearly observed. On the other hand, for any purpose of study annual average always cancels out the net fluctuations above and below the average level. In a case like fuelwood consumption where seasonal impact are very pronounced, taking annual average value may divert the result to an unrelated conclusion that will affect the adopted policy measures. In a study conducted by Khuman et al. [30] in the same study area, they observed that the actual demand levels in the watershed are season dependents since the actual fuelwood demand varies significantly according to the seasons. Thus, seasonal based modelling has been found to be more precise for reliable future consumption forecast.

The main objective of the present study is to trace future population projection and computation of the future fuelwood demand assuming the existing fuelwood consumption rate, through the following components:

1. To record variations in fuel consumption at different altitudes
2. To propose per capita fuelwood consumption model
3. To develop population dynamics model
4. To calculate future fuelwood demand with respect to changing population using simulation

2. Study area and methodology

2.1. Study area

The Phakot watershed (Fig. 1) forms the parts of Huini watershed, a part of Alaknanda–Bhagirathi sub catchments of the upper most Ganga Catchment. It lies at a distance of about 35 km from Rishikesh on Rishikesh–Tehri–Uttarkashi highway between the geographical range of 30°19′57″ to 30°22′20″N latitude and 78°16′52″ to 79°21′50 ″E longitude occupying an area of 1466 ha with an elevation range of 630–2015 m above mean sea level (amsl).

The main source of fuel and fodder in the watershed is forest and agricultural areas. But wood from dry and fallen trees is

mainly collected from the forest peripherals. Majority of the middle class families own LPG (Liquefied Petroleum Gas) but use of traditional *chulha* (Kiln) is very common for cooking. For instance, LPG is only used for preparing tea during the visit of guests, as a status symbol, which reflects the social and psychological tenor of the inhabitants. The perception behind the use of traditional fuel is zero cost incurred for fuelwood procurement.

2.2. Methodology

Basic household information like member details, educational qualification, landholding, etc. has been collected through questionnaire during the year 2006–2008 in the study area. Collection and consumption of fuelwood details have also been recorded during the survey. The survey was conducted at the selected villages in the watershed and 100% of household sampling was done in the sampled villages. Selection of sampling villages was based on distinct and non-overlapping physical characteristics and social norms. The data on decadal population figure has been collected from District Census handbook of Government of India.

Data from 246 household was collected from the watershed and the watershed segregated into three segments based on altitude and accessibility or remoteness of the villages viz. high altitude, mid altitude and low altitude. The high altitude and low altitude represents the remote category while the mid altitude is easily accessible by road.

Of the total 246 respondents, 25.2% represents remote lower altitude villages (630–1230 m amsl), 54.5% represents mid easily accessible (1030–1430 m amsl) and the rest 20.3% represents remote higher altitude villages (1230–2015 m amsl).

Population dynamics model has been constructed using first order differences on the census figures. Second order polynomials and/or linear trend has been found to give a good fit, using chi-square statistic, to the watershed data aggregated on the basis of altitude. Therefore, these models are employed to simulate future population levels, in order to understand the future demographic scenario of the region.

Regression diagnostics are used on sample survey data to model annual fuelwood consumption requirements of the watershed population. These equations have been used in conjunction with the figures projected by the population dynamics models, in order to assess the future fuelwood requirement of the watershed region (altitude wise).

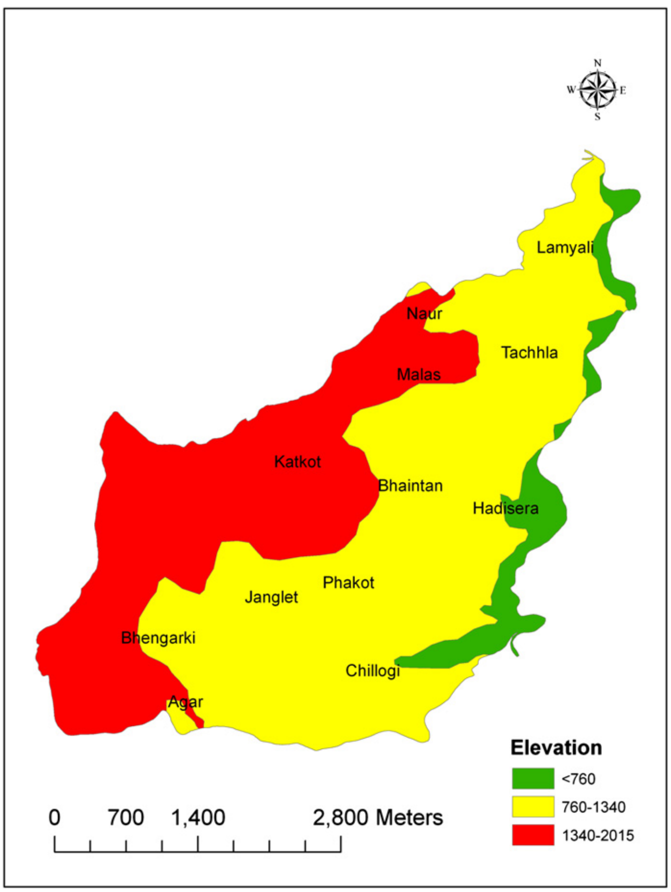

Fig. 1. Study area.

3. Result and discussion

3.1. Fuelwood energy consumption

On preliminary observation of the collected data, it is inferred that the amount of per day fuelwood consumption depends on the number of family members (i.e., family size). The family size is categorised into small (1–3), medium (3.1–6), large (6.1–9) and very large (> 9). Of the total 246 respondents in the watershed, 23% represents the small, 61% medium, 12% large and 4% as very large. Based on the data analysis and field observation, we conclude that the watershed is dominated by medium size households.

3.1.1. Variations in consumption pattern with respect to family size

The seasonal variations in fuelwood consumption relative to family size is shown in Table 1. The per capita fuelwood consumption (PCFC) value in winter is higher than the annual average suggesting the need for a season based calculation of fuelwood demand rather than employing the annual average. The decrease in PCFC value with the increase in family size is also observed in the watershed. This interesting reduction in PCFC with an increase in number of persons in the household has also been observed by Ramachandra et al. [31]. They conclude that it is

Table 1
Seasonal variations in fuelwood consumption of different family size in Phakot watershed (kg/person/day).

TAECTR	N	PCFCW				PCFCS				PCFCM				PCFCA			
		Avg	SD	CV	CI	Avg	SD	CV	CI	Avg	SD	CV	CI	Avg	SD	CV	CI
1–3 (small)	57	0.994	0.561	56.47	0.146	0.681	0.383	56.27	0.100	0.708	0.400	56.48	0.104	0.794	0.431	54.25	0.112
3.1–6 (medium)	151	0.973	0.646	66.40	0.103	0.662	0.446	67.32	0.071	0.696	0.478	68.65	0.076	0.777	0.514	66.11	0.082
6.1–9 (large)	29	0.793	0.500	63.12	0.182	0.510	0.307	60.31	0.112	0.587	0.394	67.03	0.143	0.630	0.387	61.48	0.141
> 9 (very large)	9	0.690	0.522	75.59	0.341	0.476	0.401	84.20	0.262	0.532	0.442	83.07	0.289	0.566	0.452	79.87	0.295

TAECTR: Total adult equivalent category. PCFCW: Per capita fuelwood consumption in winter. PCFCS: Per capita fuelwood consumption in summer. PCFCM: Per capita fuelwood consumption in winter. PCFCA: Per capita fuelwood consumption, annual average.

due to the co-efficiencies of cooking and water heating which result from increased scales of the family size.

During the study period, it is observed that fuelwood is primarily used for cooking and heating purpose in the domestic household sector.

3.1.2. Altitudinal variations

Altitudinal variations in fuelwood consumption are tested by using ANOVA (Table 2). At higher and mid altitude levels; fuelwood average consumption patterns across the three seasons are homogenous, though at low altitude villages fuel consumption across the season varies significantly. At the same altitude group of villages, the homogeneity in fuel consumption exists only at lower and higher altitude village echelons.

A scrutiny of fuelwood consumption data for the mid altitude villages reveals that the fuelwood consumption at village Jangleth is significantly higher i.e., fuelwood-consumption figures of village Jangleth induce an 'upward bias' in the average fuelwood consumption for the mid-altitude region. The probable reason being that their agricultural activities/produce are significantly better as compared to other villages at the same altitude making them comparatively more economically empowered. Hence, we investigate fuel consumption levels, only among the group of remaining 4 villages (Table 3) and conclude that the fuel consumption does not vary significantly across these villages.

Though, villages at a common altitude exhibit similar fuel consumption behaviour. At each altitude, it is observed, that highest consumption is in winter followed by monsoon and least consumption levels are observed in summer (Fig. 2). The seasonality influences the fuel consumption pattern only in the low level and mid level villages. Thus, we conclude that accessibility is a significant factor in generating fuel-wood consumption figures. High-altitude remote villages may have a passive season-based demand which is restricted to be translated into actual consumption due to the adverse weather conditions.

It is also observed that irrespective of season, lower altitude villages exhibit maximum fuel consumption tendency followed by mid-altitude villages. Lowest fuelwood consumption is observed in the higher altitude villages which may be due to the difference in fuelwood speceis available in the area and/or accessibility to the forest peripheries.

3.1.3. Altitude vs. family size

The impact of family size on the seasonal variations of fuelwood consumption are analysed for each altitude (Table 4).

A close perusal of Table 4 indicates that in the remote lower altitude, PCFC varies directly with the family size in families up to six members (1.021 to 1.024 in winter, 0.671 to 0.680 in summer, 0.671 to 0.697 in monsoon and 0.787 to 0.800 in an annual average) thereafter a sudden decrease in consumption levels is observed. The same trend is observed in the mid altitude villages. In the remote lower altitude and mid altitude villages, the transition in fuel consumption levels, is a function of family size up to size six. But the higher altitude villages show that there is a gradual decrease in PCFC with the increase in family size which is also observed at the watershed level (Fig. 2). It is therefore concluded that minor differences in altitude have a significant direct impact on the PCFC pattern of different household sizes in the same watershed.

3.1.4. PCFC demand model

The altitude wise PCFC model is proposed (Table 5) which portrays the household size-fuel consumption link in the watershed.

3.2. Population dynamics

The decadal population dynamics is shown in Table 6. The increases in population have direct impact on the available limited natural resources. We observed major phenomenal depletion of the inhabitants' population density over the years, which is an alarming feature from the point of view of demographic imbalance.

There is a decrease in growth rate at every altitude from 71–81 to 81–91. The mid altitude has the highest growth rate with an increase rate of 129.59 percent during 1971–1981. There is an increase in growth rate at the higher altitude (4.25 to 15.27), decrease in mid altitude (from 50.52 to 4.97) and population has been declining in the lower altitude (from 27.50 to −6.10) during 1981–2001.

Decrease in decadal growth rate is observed in mid altitude during 1971–2001. There is a sudden decrease in decadal growth rate from first decade to second decade and marginal increase from second decade to third decade in higher altitude. The decrease in growth rate is observed in lower altitude during first

Table 3
Mid altitude villages (excluding Jangleth).

Bhaintern	Bhengarki	Agar	Patta
−4.71	4.743	−4.53	5.456

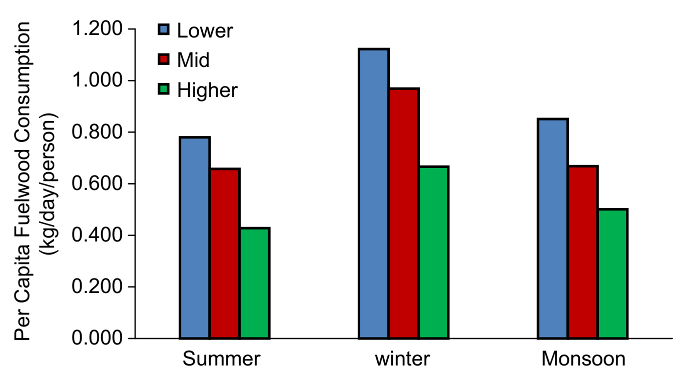

Fig. 2. Consumption in different seasons.

Table 2
ANOVA table for fuel consumption.

Group	Lower		Mid (including Jangleth)		Higher	
	F	F critical	F	F critical	F	F critical
Seasonal	14.96487*	9.552094	0.458588	3.885294	3.2220113	9.5520945
Villages	0.344051	7.708647	20.10489*	3.47805	1.037901	7.708647

* Significant at 0.05 level of significant.

Table 4
Seasonal variations in fuelwood consumption pattern in kg/person/day (altitude vs. household size).

Altitude	TAECTR	N	PCFCW				PCFCS				PCFCM				PCFCA			
			AVG	SD	CV	CI	AVG	SD	CV	CI	AVG	SD	CV	CI	AVG	SD	CV	CI
Remote lower	1–3	19	1.021	0.552	54.105	0.248	0.671	0.292	43.502	0.131	0.671	0.292	43.502	0.131	0.787	0.357	45.287	0.160
	3.1–6	38	1.024	0.506	49.356	0.161	0.680	0.268	39.403	0.085	0.697	0.263	37.667	0.083	0.800	0.329	41.117	0.105
	6.1–9	5	0.834	0.284	34.006	0.249	0.578	0.203	35.060	0.178	0.545	0.163	29.901	0.143	0.652	0.198	30.368	0.174
Mid easily approachable	1–3	32	0.988	0.612	62.011	0.212	0.696	0.452	64.985	0.157	0.720	0.483	67.070	0.167	0.801	0.504	62.881	0.175
	3.1–6	77	1.095	0.791	72.256	0.177	0.766	0.559	73.044	0.125	0.800	0.614	76.786	0.137	0.887	0.647	73.001	0.145
	6.1–9	18	0.860	0.602	69.965	0.278	0.550	0.356	64.841	0.165	0.631	0.488	77.310	0.226	0.681	0.469	68.925	0.217
	> 9	7	0.795	0.520	65.429	0.385	0.550	0.412	74.865	0.305	0.622	0.450	72.236	0.333	0.656	0.457	69.740	0.339
Remote higher	1–3	6	0.939	0.309	32.949	0.248	0.634	0.255	40.206	0.204	0.762	0.170	22.278	0.136	0.778	0.216	27.706	0.173
	3.1–6	36	0.659	0.152	23.063	0.050	0.421	0.113	26.757	0.037	0.475	0.119	24.996	0.039	0.518	0.105	20.348	0.034
	6.1–9	6	0.555	0.141	25.359	0.113	0.332	0.126	37.962	0.101	0.490	0.126	25.692	0.101	0.459	0.125	27.243	0.100
	> 9	2	0.323	0.455	140.984	0.631	0.216	0.303	140.765	0.420	0.216	0.303	140.765	0.420	0.252	0.354	140.859	0.491

TAECTR: Total adult equivalent category. PCFCW: Per capita fuelwood consumption in winter. PCFCS: Per capita fuelwood consumption in summer. PCFCM: Per capita fuelwood consumption in winter. PCFCA: Per capita fuelwood consumption, annual average.

Table 5
Altitudinal PCFC demand model.

Higher	$y=-0.0326x+0.6989$
Middle	$y=-0.0417x+0.9351$
Lower	$y=-0.0431x+1.1282$

and second decade followed by decline in population in third decade at the lower altitude. During the field visit it was observed that emigration to the nearby cities like Delhi in search of employment is the main factor for population depletion in these pockets.

3.2.1. Population projection

Census poulation data for over four decades (source: District Census Handbook, Government of India) has been used for the following time series population modelling [32]. Corresponding chi-square statistic validating the use of the models for the purpose of forecasting are displayed alongside.

Based on our modelling framework (Table 7), we can predict the population distribution at higher and mid altitude to grow at different rates in future whereas the lower altitude population growth rate is expected to remain constant in future. Expected population strength in year 2011 and 2021 is reflected in Table 8.

Population is one of the factors that indicate the level of pressure on resources. It is observed that variations in PCFC exist at different altitude across a watershed. Therefore, to calculate the future fuelwood demand, we proposed population growth model for different altitude and projected the future population. The projected future population in the watershed area is shown in Table 9. The projected population in the watershed will be 6514 in 2011 and 12,356 in 2021.These figures in conjunction with the PCFC demand model would indicate the expected fuelwood resource demand for the future in the watershed.

3.3. Extrapolated pressure on fuelwood resources

The changing human population has exercised strong pressure on the local resources in general and fuelwood in particular in the mountainous region. There is a need to calculate the future resource demand based on the population projection for wise policy-planning and decision-making. It was observed that there exists variation in the PCFC levels at different altitude in the watershed. The average seasonal and annual PCFC values in Table 10 are used to calculate the future fuelwood demand in the watershed based on the projected population.

The calculated future PCFC demand at different altitude is shown in Table 11. In the watershed, 4.531 t, 6.620 t and 4.745 t of fuelwood demand per day in summer, winter and monsoon season, respectively, to support the projected population in 2011. It is 8.548 t, 12.498 t and 8.943 t per day in summer, winter and monsoon in the year 2021. If we assumed the annual average PCFC as demand, then there will be 5.299 t per day in 2011 and 9.996 t per day in 2021 in the watershed. Based on the calculated annual average value, the total annual demand will be 1934 t in 2011 and 3648 t in 2021 for the watershed. This figure gives a rough idea of probable future fuelwood demand in the watershed at the existing consumption level.

Seasonal variations in PCFC is observed across the altitudinal categories in the watershed and the calculation of annual fuelwood demand for the year 2011 and 2021 was done based on the seasonal value (Table 12). Based on the projected population, the watershed will have a total fuelwood demand of 19,327 t in 2011 and 36,462 t in 2021.

Table 6
Decadal altitude-wise population and its percentage increase.

	Total population				% increase in population		
	1971	1981	1991	2001	1971–1981	1981–1991	1991–2001
Higher altitude	331	471	491	566	42.30	4.25	15.27
Mid altitude	507	1164	1752	1839	129.59	50.52	4.97
Lower altitude	202	360	459	431	78.22	27.50	−6.10

Table 7
Growth Rate model.

Altitude	Proposed model	Chi-square
Higher	$y=-13.511x+47.627$	.0019
Mid	$y=-62.31x+186.31$	.0009
Lower	$y=-42.159x+117.52$	.1764

Table 8
Growth rate projection (in %).

Altitude	2011	Direction of change	2021	Direction of change
Higher	−6.417	Marginal	−19.928	Decline
Mid	−62.93	Decline	−125.24	Decline
Lower	−51.116	Decline	−93.27	Decline

Table 9
Population projection.

Altitude	Population		
	2001 (census)	2011	2021
Higher	566	134.32	316.87
Mid	1839	4107.48	7990.01
Lower	431	2272.52	4049.69
Total	**2836**	**6514.32**	**12356.57**

Table 10
Seasonal PCFC demand (altitudinal).

Altitude	Summer	Winter	Monsoon	Annual average
Higher	0.428	0.666	0.501	0.532
Mid	0.658	0.969	0.668	0.765
Lower	0.780	1.122	0.851	0.918

4. Conclusions and suggestions

Fuelwood consumption differentials are studied at 3 different altitudes and across 3 different seasons. Population projection strategy is developed (Table 7) for the watershed under study. Based on sample survey conducted in the year 2006, fuelwood consumption dynamics are designed using linear regression technique (Table 5). Thus, these two models in conjunction are used to predict fuelwood consumption demand for all future times, assuming that the present growth rate dynamics hold in the future. The proposed models can be utilised to understand the impact of the future populations on the existing fuelwood resources. Therefore, it is suggested to extend this study at the macro level watershed for policy development and planning.

The decadal decrease in the population growth rates warn of population depletion due to emigration which is due to poor employment opportunities in the local areas. Therefore, efforts can be channelized towards holding the population and discourage emigration by floating appropriate livelihood avenues. These trends imply that these are neglected villages and need to focus on strengthening its economic infrastructure as a part of development activities in the region.

This study will enable understanding the demand of fuelwood due to population pressure and the consumption trend in the near future. Further, the extrapolated trend gives the policy maker to find a suitable local-specific need based alternative programmes. Here, in this study, it is indicated that if the pressure of fuelwood-consumption demand is high, then alternative interventions like electrification, providing subsidised LPG cooking etc. may be suggested. But to deliver such alternatives, the need arises to have a system with appropriate institutional frameworks, delivery mechanisms, business models, capabilities and outcome measurements tools [33] which is a time taking process in the remote areas like in Himalaya. It is in this context we may need an adhoc policy to meet the demands with an understanding to the existing policy. It is here, that the need for a study like the one we have reported here, exists to frame the sustainable fuel policy.

Maes and Vebist [17] suggest two major policy options to increase sustainability of cooking in developing countries viz. switching energy options (like solid fuel to LPG or kerosene) and increasing the sustainability of the current biomass system. In another study by Davis [34] in South Africa found that changes in fuel choices is a continual switching between different combinations and the low income group were more likely to rely on four or more fuels even if they were electrified. The same is also observed in our study area. Thus, in the remote hilly areas we suggest the second option by adopting integrated approach to rural development like promotion of agro-forestry. Plantation of locally available multipurpose tree species can be promoted in the region in the privately own land, common property land and wasteland. Such type of strategies will bring not only the solution to local fuelwood scarcity and also livelihood improvement by promoting other allied sectors like husbandry. Moreover, the promotion to use biomass as one of the source of energy (through agro-forestry, for example) in the mountainous region of Himalaya not only improved the livelihood condition but will also bring better ecological health in the upper catchment and by providing ecosystem good and services in the downstream habitats as well.

Energy development and utilisation should be placed in a sustainable development context to ensure that no dimensions, resource or policy tools are overlooked [35] and countries like India with diverse agro-climatic zones need to have local specific energy policy. Energy is needed for the livelihood and it should be considered within the overall context of community life, and energy policies and projects should be integrated in a holistic way with other improvement efforts relating to health, education, agriculture and job creation [35]. Therefore, looking into the limitations of other alternative energy sources like LPG, Solar technology, biogas etc. and understanding the social system,

Table 11
Simulated per day fuelwood requirements (in ton).

Altitude	2011				2021			
	Summer	Winter	Monsoon	Average	Summer	Winter	Monsoon	Average
Higher	0.057	0.090	0.067	0.071	0.136	0.211	0.159	0.168
Mid	2.701	3.981	2.744	3.142	5.255	7.743	5.338	6.112
Lower	1.772	2.550	1.934	2.085	3.157	4.543	3.447	3.716
Total	**4.531**	**6.620**	**4.745**	**5.299**	**8.548**	**12.498**	**8.943**	**9.996**

Table 12
Simulated seasonal based annual fuelwood requirements in the watershed (in ton).

2011				2021			
Summer	Winter	Monsoon	Annual	Summer	Winter	Monsoon	Annual
5,527	8,010	5,789	1,9327	10,428	15,123	10,911	36,462

integrated agroforestry system may be the better option to meet not only the future demand of fuelwood but also to improve the livelihood condition in the remote mountainous areas.

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